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NET ECOSYSTEM SERVICES ANALYSIS FOR MINE RESTORATION SEVEN HILLS MINE

RAMBOLL ENVIRON

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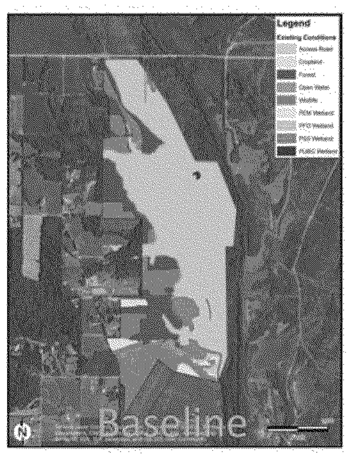
ACRONYMS AND ABBREVIATIONS

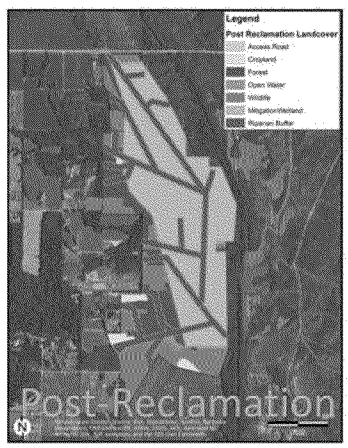
CERCLA:	Comprehensive Environmental Response, Compensation, and Liability Act
DMPA:	Dredged Material Placement Area
DSAY:	discounted service acre year
ft:	feet
HEA:	Habitat Equivalency Analysis
HSI:	Habitat Suitability Index
NESA:	Net Ecosystem Services Analysis
NOAA:	National Oceanic and Atmospheric Administration
NRDA:	Natural Resources Damage Assessment
NWI:	National Wetlands Inventory
OPA:	Oil Pollution Act
PEM:	Palustrine emergent wetland
PFO:	Palustrine forest wetland
PSS:	Palustrine scrub-shrub wetland
PUB:	Palustrine unconsolidated bottom wetland
USACE:	United States Army Corps of Engineers
USFWS:	United States Fish and Wildlife Service

EXECUTIVE SUMMARY

This Net Ecosystems Service Analysis (NESA) of Restoration at the proposed Seven Hills Mine presents an analysis of wetland areas in the onsite portion of the project. The objectives for this analysis are as follows:

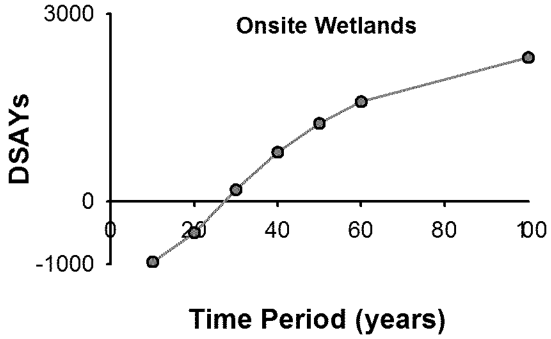
1. Document the precedence for using Habitat Equivalency Analysis (HEA) to quantify changes in ecosystem services over time by the United States Army Corps of Engineers (USACE) and other federal agencies and describe the methodologies used in this analysis;
2. Estimate the net effects (debits and credits) on ecosystem services associated with the development of the proposed Seven Hills Mine and subsequent reclamation based on delineated wetlands in the project area; and
3. Quantify onsite mitigation ratios using HEA results and a range of time scales based on precedents from other USACE mitigation projects.





HEA was developed for use in Natural Resource Damage Assessments as a tool for valuing ecosystem services over time and is explicitly endorsed by federal agencies (including the U.S. Army Corps of Engineers – USACE) for this purpose. HEA has been used by USACE at several sites around the United States to determine wetland mitigation ratios (Ray 2009). The two most complete precedents were both conducted in Florida and related to mitigation for losses of aquatic habitat associated with navigation channel expansion and shoreline protection. At a site in Miami, mitigation ratios were calculated by quantifying the net services lost and gained over a 12-year period. At another site in Broward County (Florida), mitigation ratios were calculated by quantifying the net services lost and gained over perpetuity. HEA was a useful tool for quantifying the mitigation ratios at both sites because time was a significant component of both projects. The effects of disturbance were staggered over time and the services gained by restoration accrued at a different rate than those that were lost. Because HEA incorporates the social discount rate to calculate the present value of services provided each year, it is an ideal tool for quantifying mitigation ratios where disturbance and mitigation occur over differing timescales.

This report incorporates wetland types and habitat values related to the ecosystem services provided to directly address potential wetland mitigation requirements associated with the disturbance of jurisdictional wetlands within the proposed mine operations area. Wetland habitat areas were established based on the delineation of wetland habitats described in United Mineral's Section 404 Narrative (United Minerals 2015) and wetland habitat values were estimated using a desktop wetland functional assessment approach. Those habitat values are incorporated into a HEA to quantify the potential debits and credits associated with mining and reclamation, respectively. Mitigation credits are based on project lifespans ranging from 10 years to 100 following the commencement of mining operations at the site and includes the quantification of potential credits generated in perpetuity. Because the focus of this NESA is on impacts to onsite wetlands, the substantial credits associated with onsite upland habitat reclamation and any offsite mitigation efforts are not included.



DSAYs: discounted service acre years

Potential onsite ecosystem service credits over different time periods

The results show that ecosystem service credits from onsite wetland reclamation (without offsite mitigation) could fully offset debits associated with mining activities in approximately 30 years following the commencement of operations at the site. The results from the HEA were used to quantify onsite mitigation ratios over different time periods since the start of mining operations. Consistent with the HEA results, the mitigation ratio drops below 1.0 when total services provided are summed over periods of approximately 30 years or more.

Habitat Mitigation Ratios under Different Project Lifespans

Time from Mine Open (years)	Onsite Mitigation Credit Ratio
10	2.25
20	1.19
30	0.95
40	0.86
50	0.81
60	0.79
100	0.74
Perpetuity	0.75

The results from this analysis are based on the information presented in United Mineral's Section 404 Narrative (United Minerals 2015). Where there are uncertainties in the underlying data, we have applied conservative, yet realistic, assumptions based on experience from other sites, case studies from the literature, and principals from ecology. These uncertainties can be addressed through additional habitat surveys at the site and more refined spatial modelling of disturbance effects. However, the habitat values used in this analysis are reasonable estimates of relative services provided by each habitat type. Any additional refinements based on field data would improve the habitat value estimates but would not significantly change the results.

1. INTRODUCTION

The Seven Hills Mine is a proposed surface coal mine in Warrick County, Indiana (Figure 1). The proposed permit area covers approximately 1,680 acres but includes two areas that were previously mined in the 1970s through 1990s. Extracting the coal will require excavation of overlying soil and rock including the mining of wetlands and stream habitat. Under the proposal, mining operations would commence in 2017 and would largely be limited to a 740 acre area in the northwest portion of the permit area (Figure 2). All excavated areas will be reclaimed following extraction of the coal and returned to previous land cover designations (e.g., forest and wildlife habitat, Figure 3). In addition to the onsite work, the proposed project includes an offsite mitigation project on Greathouse Island in Posey County, Indiana, which will consist of preserving and restoring approximately 1,400 acres of upland habitat.

This report describes the analysis of the potential onsite wetland and stream impacts and mitigation (reclamation and habitat enhancement actions) associated with the Seven Hills Mine to determine if the proposed onsite mitigation is adequate to generate sufficient ecosystem service credits to fully mitigate temporary impacts to wetlands. Although upland (non-wetland) habitats, both onsite and offsite, generate substantial net benefits in ecosystem services, this analysis only examines the debits and credits associated with onsite wetland habitats.

This NESA Report explicitly accounts for changes in services provided by onsite jurisdictional wetlands. The NESA was conducted based on the most readily available information for the site, including the United Mineral's Section 404 Narrative for establishing baseline and reclaimed relative habitat values (United Minerals 2015). The net ecosystem services provided over time were calculated using Habitat Equivalency Analysis (HEA).

This report was developed with the following objectives:

1. Document the precedence for using HEA to quantify changes in ecosystem services over time to determine mitigation requirements by the United States Army Corps of Engineers (USACE) and other federal agencies;
2. Complete a NESA of onsite wetlands habitat types by estimating net effects (debits and credits using HEA) on ecosystem services associated with development of the proposed Seven Hills Mine and subsequent reclamation of the delineated wetlands in the project area; and
3. Quantify onsite mitigation credit ratios using the HEA results and quantify potential mitigation credit ratios using a range of time scales based on precedents from other USACE mitigation projects.

This NESA is based on the most readily available information for the site and is intended to 1) estimate the net effects on wetlands services associated with the Seven Hills Mine, and 2) identify the variables that most significantly affect the quantification of ecosystem services in this NESA. Section 2 provides a summary of the precedence for the use of HEA to quantify ecosystem services over time with particular focus on use of HEA by the USACE. Section 3 presents the methodology and assumptions used in this analysis for delineating and assigning relative habitat value to the delineated onsite jurisdictional wetlands. Section 4 summarizes the results and identifies the factors that contribute to the uncertainty in the NESA. Section 5 provides the overall conclusions and recommendations for how the results can be interpreted.

2. HEA PROCEDURE

HEA is an environmental annuities model that has been widely adopted by state and federal agencies for quantifying the relative value of habitats and the ecosystem services they deliver to humans (Dunford et al. 2004; NOAA 2006). This section summarizes the precedence for the use of HEA by the USACE to quantify habitat mitigation ratios.

In 2008, the Ecosystem Management and Restoration Research Program of the USACE released a report exploring the application of HEA to a variety of USACE projects for calculating environmental benefits (Ray 2008). In that report, Ray (2008) acknowledges that habitat restoration is increasingly focusing on replacing ecological services rather than on simply replacing the area of impacted habitat. This is particularly applicable at sites where multiple habitat types have been impacted and those impacts change over time. HEA allows natural resource managers to quantify the services lost between the time of impact and when the restored habitat achieves full function, to determine the scale of restoration required to compensate for the lost services. Ray (2008) describes several applications of HEA by federal agencies to quantify the scale of restoration required to compensate for impacts. Not surprisingly, most of them are associated with Natural Resource Damage Assessments under the Oil Pollution Act (OPA) or the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) for which HEA was originally developed. However, Ray (2008) also describes an early application of HEA by the USACE to quantify the amount of restoration required to compensate for the loss of aquatic habitats resulting from the expansion of the Craney Island Dredged Material Placement Area (DMPA) on the Elizabeth River in Virginia. HEA was used, in part, because it was not possible to restore the vegetated, estuarine bay bottom habitat that would be lost from the DMPA expansion. Therefore, USACE used HEA to compare the types of services lost from the unvegetated bay bottom habitat with the services that could be provided from oyster reef and salt marsh habitat (Ray 2008).

A follow-up report from the same USACE office in 2009 described several additional applications of HEA on USACE projects (Ray 2009). The first application was in support of the expansion of the navigation channel in Miami Harbor that was completed in 2015[1]. As part of initial scoping to determine the extent of habitat mitigation required, HEA was used to quantify the amount of services likely to be lost from impacted reefs and hardbottom habitats in the harbor (USACE Jacksonville District 2004b). HEA was used to quantify the present value of services lost as the quality of impacted habitats degrades over time (debit) and the services provided from an acre of restored habitat (credit). This was used to determine the amount of restoration required to fully compensate for the losses. Net services were quantified over a 12-year period for low-relief hard bottom areas and over a 30-year period for high-relief hard bottom areas (USACE Jacksonville District 2004b).

The second application was in support of shoreline protection efforts in Broward County, Florida (Ray 2009). The proposed actions were projected to lead to the elimination of approximately 10 acres of hard bottom reef habitat over a three year period. HEA was used to quantify the present value of ecological services lost from that area in perpetuity to determine the size (i.e., area) of the mitigation project required to compensate for those services in perpetuity. Reef restoration was assumed to take 15 years to reach full function once the construction was complete (USACE Jacksonville District, 2004a). Using HEA, USACE concluded that 11.8 acres of restored hard bottom reef would fully compensate for the loss of 10.1 acres of hard bottom reef lost during the

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[1] http://www.saj.usace.army.mil/Media/FactSheets/FactSheetArticleView/tabid/6106/Article/479984/miami-harbor-phase-iii-dredging-project.aspx

construction of the shoreline protection project. One key assumption in the use of HEA at this site is that the benefits accrued from the mitigation project needed to balance the losses from the loss of hard bottom reef habitat when both were valued into perpetuity.

Subsequent reports and projects indicate that HEA continues to be used to quantify the appropriate scale of restoration to mitigate for adverse impacts to habitats from USACE projects in the Jacksonville District (AECOM 2014; USACE 2014). HEA is a useful tool for these types of projects because the effects of disturbance frequently occur over different time scales than the increase of services from the mitigation projects. HEA accounts for those different time scales by applying a social discount rate to quantify the present value in order to balance future service gains and losses.

3. METHODOLOGY

To conduct this NESA, Ramboll Environ used HEA to quantify the flows of ecosystem services over time from the proposed onsite mitigation areas associated with the Seven Hills Mine. Onsite wetland services are quantified for the proposed operations area illustrated in Figure 2. The wetland types are explicitly included in the habitat delineation and valuation in this NESA (Table 1). The baseline habitat conditions used are illustrated in Figure 3 and the post-reclamation habitat conditions are illustrated in Figure 4. The baseline conditions are based on the delineated wetland habitat areas presented in Map B of Appendix A in United Mineral's Section 404 Narrative (United Minerals 2015) and the post-reclamation conditions are based on the reclaimed wetland areas presented in Map C of Appendix A in the Section 404 Narrative (United Minerals 2015). This section provides an overview of the HEA parameters including habitat areas and values, recovery rates, mine operations and timing, and discount rate. It also describes how the relative habitat values under baseline and reclaimed conditions were developed for onsite wetlands.

3.1 Habitat Equivalency Analysis Overview

The potential value of proposed restoration actions for the mitigation at the Seven Hills Mine were quantified using HEA. As described in Section 2, HEA is one of the methodologies explicitly endorsed for quantifying ecosystem service flows in the United States Department of Interior (USDOI) regulations (43 CFR 11.83(c)(2)). Under HEA, ecosystem service flows are quantified based on the area of habitat required to maintain them, thus allowing for direct comparison of services gained through restoration actions with losses resulting from injuries to natural resources. The following input parameters are required to complete the HEA:

- Area disturbed and reclaimed (onsite) in acres
- Wetlands types within the Seven Hills Mine.
- Relative habitat quality throughout the project area prior to disturbance, during mining operations, and following completion of the reclamation actions (unitless)
  Habitat quality is scored on a scale of 0 (no habitat value) to 1 (maximum habitat value) similar to the United States Fish and Wildlife Service's (USFWS) Habitat Suitability Indices (HSIs)[2].

  The level of ecosystem services provided are assumed to be directly proportional to the habitat quality score. This approach was developed by the National Oceanic and Atmospheric Administration (NOAA) as part of the Natural Resource Damage Assessment (NRDA) for the Hylebos Waterway in Tacoma Washington to quantify potential damages associated with sediment contamination and potential credits associated with offsite compensatory restoration actions (Chapman and Taylor 2002). This general approach has been adopted at numerous other sites.
- Time frame of project impacts and benefits (start year and end year)
- Slope and shape of the ecosystem service recovery curves (e.g., linear, logarithmic, sigmoidal, etc.) following reclamation
- Social discount rate for estimating the social value of future natural resource services (percent, %)

[2] http://www.nwrc.usgs.gov/wdb/pub/hsi/hsiindex.htm

These parameters are combined to quantify the natural resource services gained (credits) or lost (debits) in the onsite portion of the project as indicated in the following equation:

Equation 1

$$DSAY_s = \sum_{l} \sum_{t=t_0}^{n} (H_{lt} - H_{lb}) \cdot DF_t \cdot A_l$$

Where:

$DSAY_s$:	Discounted service acre years associated with the Seven Hills Mine where a negative value indicates net debit and a positive value indicates a net credit to ecosystem services
l:	Habitat or land cover type. For the purposes of this analysis, six habitat types were evaluated (described in detail below).
t_0:	Year mining operations commence (2017)
n:	Final year of project timeline (the last year that credits/debits are tallied). For the purposes of this analysis, the project timeline varied from 10 to 100 years following the start of mining operations (2027 – 2117)
H_{lb}:	Baseline habitat suitability value of habitat type *l*
H_{lt}:	Habitat suitability value of habitat type *l* in year *t* following the commencement of mining operations
DF_t:	Discount factor for year *t* given a base year of 2016
A_l:	Number of acres disturbed and reclaimed within habitat type *l*

The discount factor (DF) is calculated based on the social discount rate using the following equation:

Equation 2

$$DF_t = \frac{1}{(1+\rho)^{t-t_0}}$$

Where:

DF_t:	discount factor in year *t*
ρ:	Social discount rate (%)
t:	year
t_0:	present year

The approach for developing the habitat quality values, recovery curves for each habitat type, and additional parameter values is summarized in Sections 3.2 through 3.4.

3.2 Ecosystem Service Level Estimates

As described above, a quantitative approach is used to estimate the level of ecosystem services provided by each habitat type. Total ecosystem services are assumed to be proportional to the relative habitat value such that the highest quality habitat (often called the "gold standard") is assumed to provide maximum services. The level of ecosystem services provided by the other habitat types are estimated relative to the "gold standard" habitat. The relative habitat scores used in this NESA are listed in Table 1.

The focus of this assessment are the areas designated as wetlands in United Mineral's Section 404 Permit application (United Minerals 2015). Changes to baseline habitat value were quantified over the area to be disturbed as described in the onsite Operations Map (within Appendix A of the Section 404 Permit, United Minerals 2015). This is the approximately 740 acre area highlighted in Figure 2. This NESA includes stream and riparian corridor habitat in its assessment of ecosystem services (Table 1). The basis for the baseline and enhanced habitat values for each habitat type are provided below.

3.2.1 Palustrine Wetland Habitat

To determine the baseline and post-reclamation wetland habitat values, a desktop wetland functional assessment was performed using a modified National Wetlands Inventory (NWI) Plus methodology. The NWI Plus methodology was developed by the USFWS for watershed level preliminary assessments of wetland function and ecosystem services (Tiner 2003, 2011a, 2011b). The NWI Plus methodology is based on the Hydrogeomorphic Classification (HGM), which was developed by the USACE to evaluate wetland functions and services. This approach was used because the USACE Louisville District's webpage specifically identifies HGM methodologies for conducting wetland assessments.

The onsite wetlands were previously delineated and categorized according to Cowardin classification into four wetland types including Palustrine Forested (PFO), Palustrine Scrub-shrub (PSS), Palustrine Emergent (PEM), and Palustrine Unconsolidated Bottom (PUB). The wetlands within these groups were then assessed for landscape position, landform, and flow direction. The assessment included analysis of current aerial photography, topography data, hydrological data and wetland delineation forms. Results of the assessment were used to score the following wetland functions identified by Tiner (2003):

1. Surface water detention
2. Stream flow maintenance
3. Nutrient water detention
4. Carbon sequestration
5. Sediment and other particulate retention
6. Bank and shoreline stabilization
7. Provision of fish and aquatic invertebrate habitat
8. Provision of water bird habitat
9. Provision of other wildlife habitat

The functions were scored based on three potential values. A numerical value of 0.0 was assigned if the wetland does not provide the function; a numerical value of 0.5 was assigned for a moderate level of function; and a value of 1.0 was assigned for a high level of function (Table 2). The individual wetland function values were averaged to determine a single wetland functional value for each wetland type. Wetland functions were estimated for reclaimed PFO wetlands by assuming that improved connectivity to active stream floodplains provides greater wetland function at maturity.

3.2.2 Stream

Streams make up a small portion of the total area over which the baseline and post-reclamation ecosystem services were calculated. However, post-mine mitigation plans stipulate that onsite stream and floodplain wetland reclamation will be a key component of the post-mine reclamation efforts. For the purposes of this NESA, restored streams bordered by enhanced riparian corridors are assumed to provide the highest level of ecosystem services per area of all the habitat types considered in this NESA. Because the habitat values are quantified on a relative scale, the combined enhanced stream and riparian corridor land use types are assigned a habitat value of 1.0 (Table 1). The baseline habitat value for the onsite streams (Table 3) is based on the habitat scores for the streams indicated as impacted in United Mineral's Section 404 Permit (United Minerals 2015). The average habitat score based on the United States Environmental Protection Agency's (USEPA's) Rapid Bioassessment Protocal (RBP) (Barbour et al. 1999) for these streams is 108 on a scale from 0 to 200 (or 0.54 out of 1.0, summarized in Table 3). The streams that will be impacted and reclaimed are all classified as either intermittent or ephemeral streams, yet the RBP methodology was developed for wadeable streams (Barbour et al. 1999). Therefore, several of the habitat metrics were dependent on standing water in the stream channels and the onsite intermittent and ephemeral streams scored poorly in all cases (Table 3). Because it is not reasonable to expect that post-reclamation conditions in the intermittent and ephemeral creeks shown on Figure 4 will be consistent with the maximum habitat score from the RBP due to the lack of continuous flowing water, the baseline habitat value for the onsite streams is adjusted to eliminate the metrics from the RBP that are associated with continuous flow. Therefore, the habitat scores in Table 3 are adjusted to exclude the metrics dependent on continuous water flow and the adjusted maximum possible score is assumed to be 140 rather than 200[3]. Using this intermittent stream adjustment habitat value, the baseline habitat score for onsite streams is set equal to the length-weighted average habitat score for the onsite streams, approximately 0.70 (Table 3).

As described in the Section 404 Permit Narrative (United Minerals 2015, page 45), "affected streams and wetlands will be mitigated to a higher quality than what currently exists. Mitigated streams are typically sinuous with instream habitat structures, riffle/pool complexes, rock beds, and adequate riparian buffers." In addition, reclamation of terrestrial portions of the site is expected to increase the infiltration capacity of the soil, which may decrease surface run-off and increase baseflows to reclaimed streams. Therefore, the combined enhanced stream and intact riparian buffers are assumed to provide the maximum level of ecosystem services among the habitat types considered in this analysis.

3.2.3 Riparian Corridor

The riparian corridor for this project is defined as the 100 feet (ft) wide buffer of riparian habitat on both sides of the river or stream. Most onsite streams surveyed in 2014-2015 are reported to currently have at least 100 ft of woody riparian buffer on both sides and the forested wetlands adjacent to the streams that will be reclaimed following mine activities (PFO 1 in the Section 404 Permit Narrative) are dominated by native deciduous tree species (*Fraxinus pennsylvanica* or green ash, *Acer negundo* or box elder, and *Ulmus rubra* or slippery elm). Despite the intact riparian corridor and predominantly native species composition, the riparian corridors of the onsite streams are not assigned maximum potential value under baseline conditions because, for the purposes of this NESA, riparian habitat value is dependent on connection to high quality stream habitat. As discussed above, even after accounting for the intermittent nature of streamflow in the onsite

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[3] Metrics 1) epifaunal cover, 3) pool variability, and 5) channel flow in Barbour et al. 1999. The maximum score for each of these metric is 20 contributing, together, a maximum of 60 points out of 200 towards the total habitat score.

streams, habitat quality in the onsite streams is relatively low (Table 3). This concept of making aquatic and terrestrial buffer habitat quality dependent on each other is consistent with the approach used by the Trustees in the NRDA for the Hylebos Waterway in Tacoma, Washington, where fully functioning estuarine marsh habitat required connection to intact riparian buffer habitat to receive its maximum potential habitat value (Iadanza 2001).

For the purposes of this NESA, the baseline habitat value for riparian corridors are assigned based on the land cover designation in the land cover map of the site (Figure 3). The area of the riparian corridor in Table 1 is estimated based on the length of reclaimed streams illustrated in Figure 4 and the proposed buffer widths of 100 ft. for each.[4]

3.2.4 Open Water

Open water habitat within the mine boundary of the onsite area is minimal (less than 5 acres) so this land cover designation does not significantly affect the NESA results. The baseline habitat value for the open water areas is assumed to be greater than the baseline habitat value for the onsite streams because the open water areas are permanent rather than intermittent. Open water provides continuous aquatic habitat throughout the year. Based on Figure 3, the onsite open water areas are surrounded by forest and wildlife habitat so they are assumed to provide reasonably high quality habitat. Therefore, the baseline habitat value for open water areas is assumed to be 0.75. For the purposes of this analysis, post-reclamation habitat value of open water is assumed to increase by 15% above its baseline value. This estimate is based on best professional judgment due to improvements in the soil and plant community composition surrounding the open water areas (United Minerals 2015).

3.3 Recovery Curves

For the purposes of this NESA, recovery from disturbance and maturation of ecosystem services following reclamation are assumed to be nonlinear. That is, services are predicted to rebound relatively quickly in the short term but then slow as the services approach full function. Recovery in the HEA is modeled as a logarithmic curve. The times to achieve full function assumed in this NESA differ by habitat type and are listed in Table 1.

As defined in the Section 404 Permit (United Minerals 2015), mining operations are expected to last for 7 years. The level of ecosystem services provided is assumed to drop to 0 during mine operations for all habitats. Mining operations are projected to suppress ecosystem services from aquatic habitats (streams and open water) for the full 7-year period that the mine is operational. However, the palustrine wetland habitats are assumed to be impacted incrementally such that 1/7th of the area is impacted each year and recovery commences in that disturbed after a two year lag in ecosystem services. Figure 5 illustrates how the mining impacts are projected to occur in the palustrine forested (PFO) area using the recovery function described above. Aquatic habitats are assumed to be uniformly impacted over the entire lifespan of the mine and those impacts are complete (i.e., 0 services provided). Recovery is assumed to begin immediately following the completion of mining activities.

The stream and open water recovery rates of 5 years are based on results from the Busseron Creek Restoration Project (Hall et al. 2014) and by data from stream restoration efforts compiled by the

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[4] The post-mine reclamation plan indicates that 100 ft wide (from both sides of the stream) will be established for intermittent and perennial streams but that buffers around ephemeral streams will be 50 ft. For the purposes of this analysis, all buffers are assumed to be 100 ft wide from all streams.

Maryland Department of Natural Resources (MDNR).[5] The 50-year recovery period for palustrine and riparian forests is also based on restoration data compiled by MDNR and from previous work on restoration of reclaimed mine lands. Those studies suggest that there is rapid short-term recovery of many services but that full canopy cover restoration takes longer (Burger and Zipper 2010, Burger et al. 2010) suggesting that logarithmic curves are an accurate reflection of recovery patterns for forest habitats.

3.4 Additional Parameter Values

In addition to the parameters related to ecosystem service levels under baseline and post-reclamation conditions and the recovery patterns for those services, values for the additional parameters required for the HEA are summarized below:

- Mine operations start in 2017 and the operations proceed for 7 years. Mining operations are assumed to be complete in 2023.
- Social discount rate is assumed to be constant at 3% (NOAA 1999) and all services are discounted based on a present year of 2016.
- The total time period over which service credits and debits are quantified is uncertain. Therefore, the project lifespan was variable from a minimum of 10 years to 100 years following the start of mining operations in 2017. Because there is USACE precedent for valuing services into perpetuity (Section 2), potential credits and debits are quantified over perpetuity. The results discussed below are presented as the total DSAYs accumulated over the range of project lifespans.

3.5 Mitigation Ratio Calculation

To quantify the mitigation ratio for onsite wetlands reclamation, the HEA results for the following land cover types were separated into losses and credits:

- Wetlands (PFO, PEM, PSS, and PUB)
- Open water
- Streams
- Riparian corridor

The total debits and credits associated with each land cover type, expressed as DSAYs, were summed over the time periods are presented in Table 4. The net losses were divided by the net gains to generate the mitigation ratio for each time period. This is the same approach used by the USACE to quantify the mitigation ratios in the precedents described in Section 2 (USACE Jacksonville District 2004a, 2004b).

[5] http://www.dnr.state.md.us/forests/programapps/rfbrestoration.asp

4. RESULTS

Results are presented in Table 4 and Figure 6. Total ecosystem service credits and/or debits are quantified based on a range of time periods from 10 years to 100 years following the start of mine operations. Quantification of values are also provided into perpetuity for the NESA results and the resultant mitigation ratios for the onsite wetlands corresponding to each aggregate time period.

The final results are sensitive to the time period over which debits and credits are quantified and the rate that habitats recover from disturbance. Based on the recovery functions assumed for this analysis, services gained from onsite reclamation actions could completely offset services lost during mining operations in approximately 30 years (Figure 6). This is consistent with the mitigation ratio results where a 1:1 ratio would be achieved if the total services provided by onsite wetlands are summed over a minimum of 30 years following the start of mining operations. The majority of the onsite credits potentially generated are associated with enhancements to the PFO wetlands and riparian corridor. After about 50 years, the continued maturation of reclaimed onsite wetlands is predicted to have generated more than double the amount of services that were lost during mine operations. When valued over perpetuity, the reclaimed onsite wetlands are predicted to generate nearly triple the services estimated to be lost during mine operations.

Because the analysis for this NESA is on impacts to onsite wetlands, the substantial credits associated with onsite upland habitat reclamation and any offsite mitigation efforts are not included.

5. UNCERTAINTIES AND SENSITIVITIES

The key areas of uncertainty in this analysis are the baseline level of ecosystem services provided at the Site and the rate at which those services recover from disturbance. Although the habitat quality at the Site is likely to be more complex than represented in this NESA, it is wholly consistent with the land cover designations in the pre- and post-reclamation maps presented in the Section 404 permit application (United Minerals 2015). This NESA could be refined by conducting field surveys of the habitat present at the site, noting key habitat features such as the plant community composition and age structure, and a thorough review of the scientific literature on post-reclamation ecosystem recovery rates for the terrestrial and aquatic habitats found at the Seven Hills Mine. We believe that the habitat values used in this analysis (Table 1) are reasonable estimates of relative services provided by each habitat type and that additional refinements based on field data would improve the habitat value estimates but would not significantly change the values.

Assignment of individual function values was based on a desktop review of aerial imagery, site descriptions, and geographical information systems (GIS) layers. In addition, the wetland functional values were applied on a site-wide basis rather than on a more fine-grained site-specific basis. To evaluate the sensitivity of the NESA results to the assignment of wetland functional values, we independently adjusted the baseline and post-reclamation wetland habitat values by 25% to determine the effect on the time required for service gains and losses to balance. A 25% increase in baseline habitat value for PFO wetlands (i.e., from 0.61 to 0.76) or a 25% decrease in post-reclamation habitat value for PFO wetlands (i.e., from 0.89 to 0.67) increases the time required for services to balance from approximately 30 years to approximately 50-60 years. However, the habitat values developed for this report are intended to be unbiased estimates of ecosystem services and are as likely to be overestimates as they are underestimates. The 30-years required for services to balance, therefore, is a central tendency estimate.

The list below summarizes some of the uncertainties in the key parameters used in this NESA. They are listed in decreasing order of importance:

1. Selection of ecosystem service metrics: The term Ecosystem Services applies to a broad range of potential services and its lack of specificity can be a liability in translating the benefits of NESA to regulators. It is, therefore, helpful to be as explicit as possible in defining the types of services captured by the NESA. One option for doing this is to use previously developed habitat quality indices that have been widely adopted for a variety of purposes (e.g., USEPA's Rapid Bioassessment Protocol or USFWS' HSIs). Another option is to select a quantifiable metric that can be measured in the field (e.g., biodiversity index, fish or wildlife counts, stream base flow measurements, percent vegetative cover, etc.) as a direct proxy for the most important ecosystem services. Ecosystem services in this NESA are based on the available data on habitat quality at the site and proposed reclamation actions in the Section 404 permit application (United Minerals 2015).

2. Recovery Rates: The estimation of appropriate ecosystem service recovery rates following reclamation is dependent on the metric used to represent ecosystem services. Therefore, any refinements to the approach for quantifying ecosystem services will require refinements to the recovery rates applied in the HEA model. For example, once ecosystem service metrics have been identified, data from the scientific literature and from field surveys of previously mined areas adjacent to the proposed Seven Hills Mine can be used to adjust recovery rates specific to the metric selected. Recovery rates in this NESA are, to the greatest extent possible, based on

recovery rates reported from other mine sites (e.g., Burger and Zipper 2010, Burger et al. 2010, Hall et al. 2014).

3. This analysis is restricted to the onsite debits and credits from wetland restoration. There is substantial ecosystem service value in the reclamation of onsite upland habitats and the approximately 1,400 acre Greathouse Island offsite restoration and preservation into perpetuity. There would be a significant increase in the DSAYs provided by these restoration efforts and a decrease in the number of years it would require to have a 1:1 mitigation ratio. Therefore, this NESA does not account for the significant gains in ecosystems services that are provided based on upland and offsite habitat restoration.

4. Abandoned Mine Land (AML) Program: The Section 404 Permit Narrative (United Minerals 2015) indicates that, if permitted, the Seven Hills Mine Project is likely to contribute a minimum of $700,000 per year to the AML program to remedy adverse effects of past coal mining in Indiana prior to the establishment of the Surface Coal Mine Control and Reclamation Act of 1977. These funds will also allow for an increase in ecosystem services in areas previously degraded by mining impacts outside of the Seven Hills Mine area. These are separate and apart from onsite reclamation and offsite mitigation efforts that are part of proposed Seven Hills Mine. This NESA does not account for any gains in ecosystem services that are generated by restoration projects funded from contributions to the AML program.

5. Spatially-explicit analysis of disturbance patterns: This NESA does not account for the spatial pattern of disturbance during mining operations. While a more refined NESA for the Site could use the operations plans for the Site to map the annual footprint of disturbance and reclamation to refine the estimates of ecosystem service changes over time, there is no reason to conclude that the higher level approach used in this NESA biases the results in one direction or the other.

6. CONCLUSIONS

The NESA conducted for the Seven Hills Mine explicitly accounts for potential effects on jurisdictional wetlands. It is a desktop analysis based on the information for the site presented in the Section 404 Narrative (United Minerals 2015). To explicitly account for the onsite wetland area and value, the report includes the use of HEA to calculate wetland mitigation ratios based on a range of aggregate time periods following the start of operations at the site.

The conclusions from this analysis are as follows:

- HEA is a flexible tool that can be used to calculate mitigation ratios and it has been explicitly used for that purpose by the USACE and other federal agencies at other sites.

- Because HEA incorporates a social discount rate of 3%, it allows for evaluation of temporal effects on ecosystem services.

- In previous applications of HEA for quantifying mitigation ratios, USACE has considered ecosystem services summed over time periods ranging from 12-years to perpetuity. Other federal agencies commonly use 30- to 50-year time periods for the purpose of evaluating cumulative ecosystem services (e.g., NRDAs).

- Following a maximum loss of aggregate wetlands services for 10 years after the start of mine operations (approximately 1,000 DSAYs), onsite reclamation activities are predicted to fully offset those losses in about 30 years.

- After about 50 years, the continued maturation of reclaimed onsite wetlands is predicted to generate double the amount of services that were lost during mine operations.

- When valued over perpetuity, the reclaimed onsite wetlands are predicted to generate nearly triple the services estimated to be lost during mine operations.

- The wetland mitigation ratios indicate that the proposed onsite wetlands reclamation actions will be sufficient to mitigate for all wetlands services lost during the 7-year mine operations if net services are quantified over at least 30 years following the start of mine operations. No offsite mitigation efforts would be required.

- This analysis focuses solely on impacts to onsite wetlands and does not account for additional services generated by onsite upland enhancements or any offsite mitigation work. By excluding these additional activities that are associated with the Seven Hills Mine, this NESA is conservative in that it does not fully account for all benefits that will be generated as part of the project.

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Table 1. Relative Habitat Values and Time to Full Function for Onsite Wetlands at the Proposed Seven Hills

Habitat Type	Baseline Conditions (ac)[a]	Baseline Habitat Value	Post-Restoration Area (ac)[b]	Reclaimed Habitat Value	Time to Full Function (yrs)
Palustrine Forested Wetland (PFO)	442.1	0.61	348.7	0.89	50
Palustrine Scrub-shrub Wetland (PSS)	29.0	0.50	NA	NA	10
Palustrine Emergent Wetland (PEM)	3.8	0.78	NA	NA	5
Palustrine Unconsolidated Bottom (PUB)	1.7	0.44	NA	NA	5
Open Water	4.7	0.75	5.5	0.90	5
Riparian Corridor[c]	NA[d]	NA	108.1	1.0	50
Stream	9.8	0.70	9.8	1.0	5
Total	**491**		**472**		

a. Baseline indicates current conditions
b. Post-Restoration indicates the relative habitat value following reclamation where native plant species are dominant.
c. The riparian corridor is defined as a 100 feet (ft) buffer on either side of a river or stream. For the purposes of this analysis, approximately 40 acres of riparian corridor that are outside of the delineated post-reclamation wetlands are conservatively excluded from the analysis.
d. Under baseline conditions, the stream channel is typically highly channelized and the habitat value of the terrestrial portion is assigned the value of the habitat type present (e.g., forest or wildlife).
Note: Habitat values for palustrine wetlands are derived in Table 2 while stream habitat values are derived in Table 3. All other habitat values are qualitatively described in the NESA Report.

ac: acres
NA: Not applicable under either the baseline or reclaimed habitat conditions.
yrs: years

Table 2. Preliminary Wetland Functional Assessment for Onsite Wetlands in Proposed Seven Hill Mine Site

			Wetland Function Value									
Wetland Type	**Condition**	**Hydrogeomorphic Assessment**	**Surface Water Detention**	**Stream Flow Maintenance**	**Nutrient Water Detention**	**Carbon Sequestration**	**Sediment and Other Particulate Retention**	**Bank and Shoreline Stabilization**	**Provision of Fish and Aquatic Invertebrate Habitat**	**Provision of Water Bird Habitat**	**Provision of Other Wildlife Habitat**	**Average Score**
PFO	Baseline	Terrene Flat Former Floodplain Wetland Throughflow-entrenched	0.5	0.5	1	1	0.5	0	0.5	0.5	1	0.61
	Reclaimed	Lotic Stream Low Gradient Floodplain Flat Wetland Throughflow	1	1	1	1	1	1	0.5	0.5	1	0.89
PSS	Baseline	Lotic Stream Low Gradient Floodplain Flat Wetland Throughflow	0.5	0.5	1	0.5	0.5	0.5	0	0.5	0.5	0.50
PEM	Baseline	Lentic Fringe Wetland Bidirectional-nontidal	1	0.5	1	1	1	0.5	0.5	1	0.5	0.78
PUB	Baseline	Terrene Basin Wetland Inflow	0.5	0	0.5	0.5	0.5	0	1	1	0	0.44

PEM: palustrine emergent
PFO: palustrine forest
PSS: palustrine scrub-shrub

Table 3. Onsite Habitat Scores for Streams that will be Impacted by Mine Development

Stream ID	Type	Length (ft)	Field Score[a]	Habitat Score	Flow Adjusted Habitat Score[c]
Stream 13	Ephemeral	1,160	29	0.15	0.21
1NS1.1A	Ephemeral	186	122	0.61	0.87
1NS1.1B	Ephemeral	232	115	0.58	0.82
1NS1.2A	Ephemeral	75	114	0.57	0.81
1NS1.4A	Ephemeral	748	104	0.52	0.74
1NS2A-1	Ephemeral	531	128	0.64	0.91
1NS2A1	Ephemeral	533	119	0.60	0.85
1NS2A2	Ephemeral	265	124	0.62	0.89
1MS3A-2	Ephemeral	168	102	0.51	0.73
1MS3B	Ephemeral	264	110	0.55	0.79
1MS3B1	Ephemeral	64	104	0.52	0.74
1NS3C-1	Ephemeral	251	133	0.67	0.95
1NS12A-1	Ephemeral	289	110	0.55	0.79
1MS12B-1	Ephemeral	316	112	0.56	0.80
1NS12C	Ephemeral	252	99	0.50	0.71
1NS12D	Ephemeral	124	85	0.43	0.61
1NS12E	Ephemeral	100	106	0.53	0.76
1NS14	Ephemeral	497	109	0.55	0.78
1NS15	Ephemeral	181	121	0.61	0.86
1NS16B	Ephemeral	110	118	0.59	0.84
1NS18	Ephemeral	341	117	0.59	0.84
1NS19	Ephemeral	562	121	0.61	0.86
1RS3-1	Ephemeral	307	97	0.49	0.69
1RS3A	Ephemeral	193	97	0.49	0.69
1RS5	Ephemeral	197	97	0.49	0.69
1RS6-4	Ephemeral	318	102	0.51	0.73
1RS6A	Ephemeral	163	98	0.49	0.70
Stream 1	Intermittent	10,910	97	0.49	0.69
Stream 1.1	Intermittent	2,814	80	0.40	0.57
Stream 1.2	Intermittent	4,346	67	0.34	0.48
Stream 1.3	Intermittent	1,755	74	0.37	0.53
Stream 1.4	Intermittent	1,820	106	0.53	0.76
Stream 2	Intermittent	3,273	101	0.51	0.72
Stream 3	Intermittent	3,099	85	0.43	0.61
Stream 4	Intermittent	1,888	78	0.39	0.56
Stream 10	Intermittent	206	66	0.33	0.47
Stream 12	Intermittent	2,793	82	0.41	0.59
1MS1A	Intermittent	1,219	123	0.62	0.88
1NS1B	Intermittent	902	132	0.66	0.94
1NS1.1C	Intermittent	634	133	0.67	0.95
1NS1.1D	Intermittent	884	114	0.57	0.81
1NS1.3A	Intermittent	1,117	114	0.57	0.81
1NS1.3B	Intermittent	531	121	0.61	0.86
1NS1.3B1	Intermittent	207	125	0.63	0.89
1NS1.4B	Intermittent	169	120	0.60	0.86
1NS2A	Intermittent	1,324	129	0.65	0.92
1MS3A	Intermittent	111	111	0.56	0.79
1MS3A-1	Intermittent	578	109	0.55	0.78
1NS3C	Intermittent	741	135	0.68	0.96
1NS4.1	Intermittent	183	93	0.47	0.66
1NS4.2	Intermittent	249	102	0.51	0.73
1NS12B	Intermittent	257	119	0.60	0.85
1NS16	Intermittent	1,134	122	0.61	0.87
1NS16A	Intermittent	427	121	0.61	0.86
1NS17	Intermittent	681	127	0.64	0.91
1RS6	Intermittent	301	134	0.67	0.96
1RS6-1	Intermittent	121	118	0.59	0.84
1NS6-2	Intermittent	105	116	0.58	0.83
1NS6-3	Intermittent	149	109	0.55	0.78
1NS7	Intermittent	285	124	0.62	0.89
Length-Weighted Average Habitat Score (all)					*0.70*

a. Field score is based on a scale of 0 to 200 (Barbour et al. 1999). Surveys completed in 2014 and 2015.

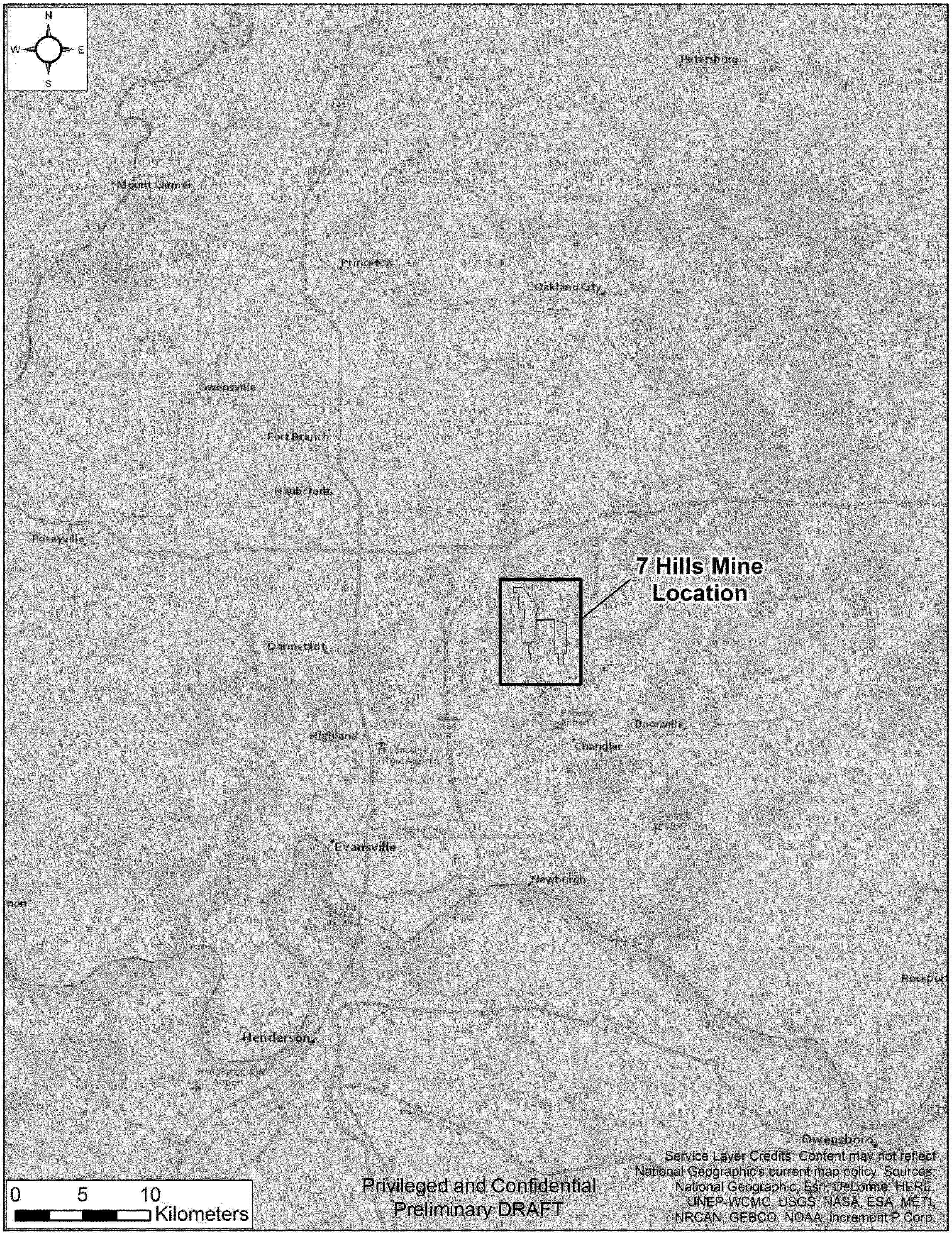
b. Adjusted habitat scores are calculated based on a maximum potential value of 140 rather than 200. This excludes the 3 metrics developed by Barbour et al. (1999) that are most closely associated with continuous flow.

ft: feet

Table 4. Preliminary NESA Results and Mitigation Ratios for the Proposed Seven Hills Project (Onsite)

Time from Mine Open (yrs)	Wetlands DSAYs	Mitigation Ratio
10	-968	2.25
20	-499	1.19
30	191	0.95
40	785	0.86
50	1,247	0.81
60	1,595	0.79
100	2,301	0.74
Perpetuity	2,490	0.75

DSAYs: discounted service acre years
NESA: Net Ecosystem Services Analysis
yrs: years



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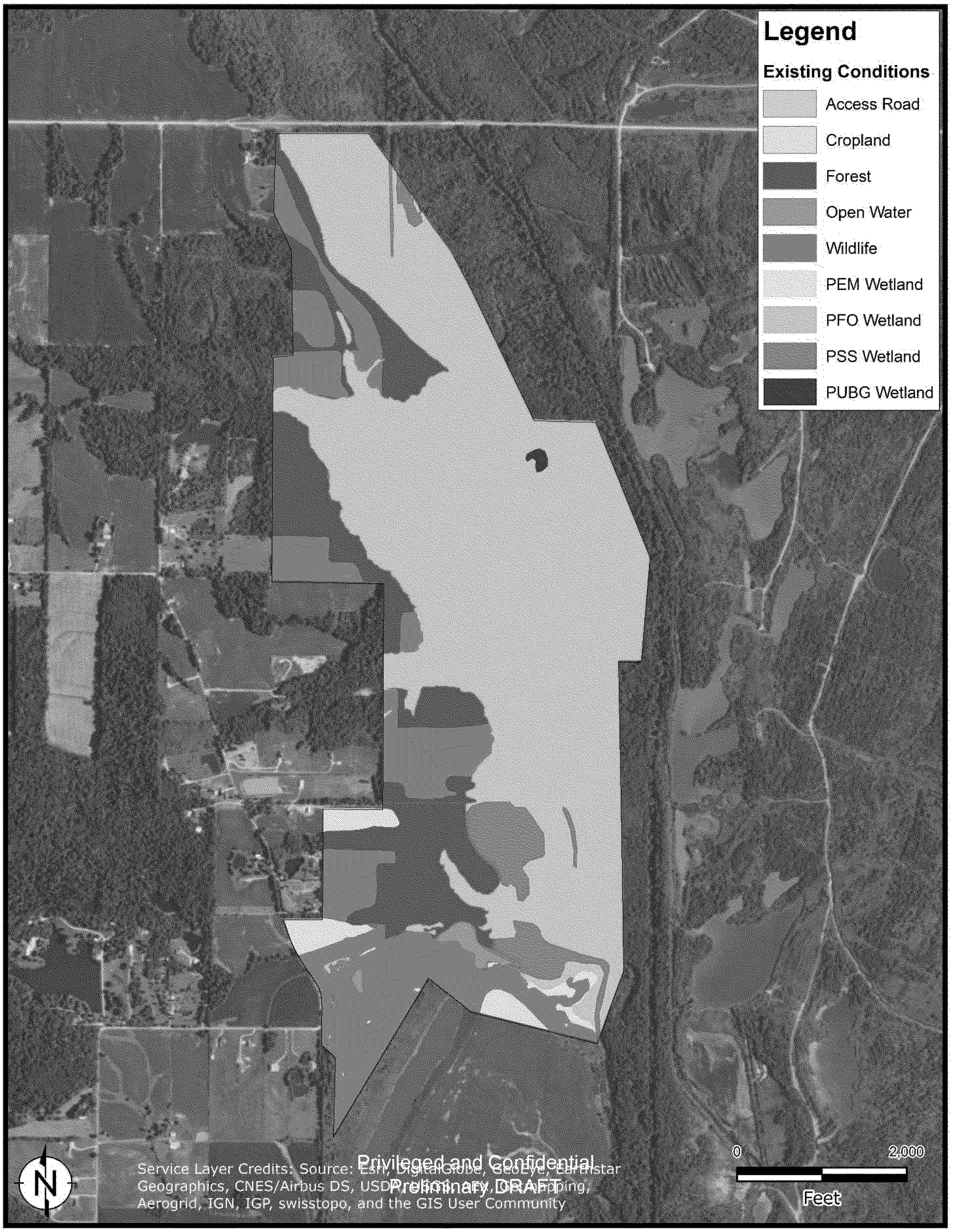
Proposed Seven Hills Mine Location

Figure 1

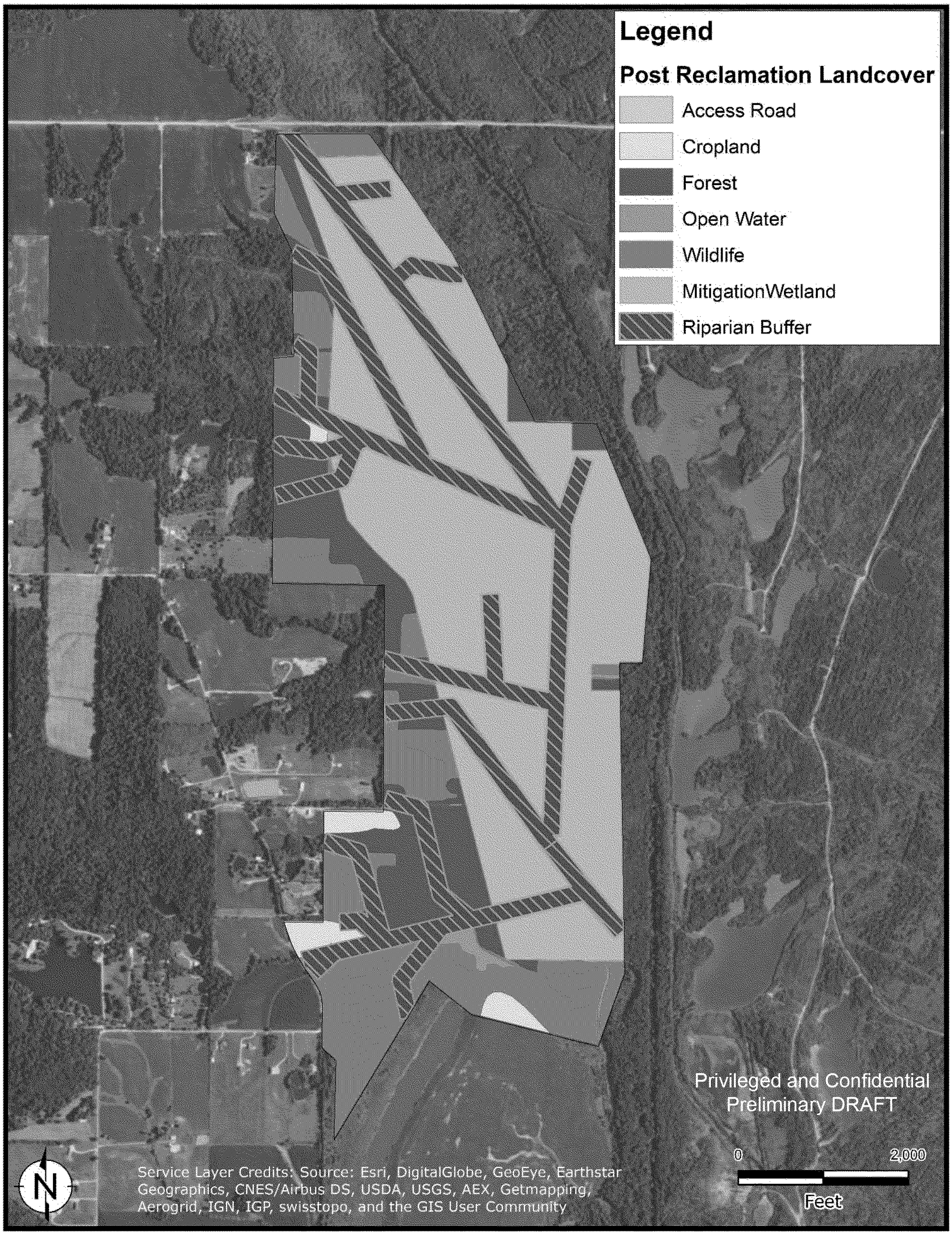
RAMBOLL ENVIRON

Proposed Operations Area: Seven Hills Mine Site

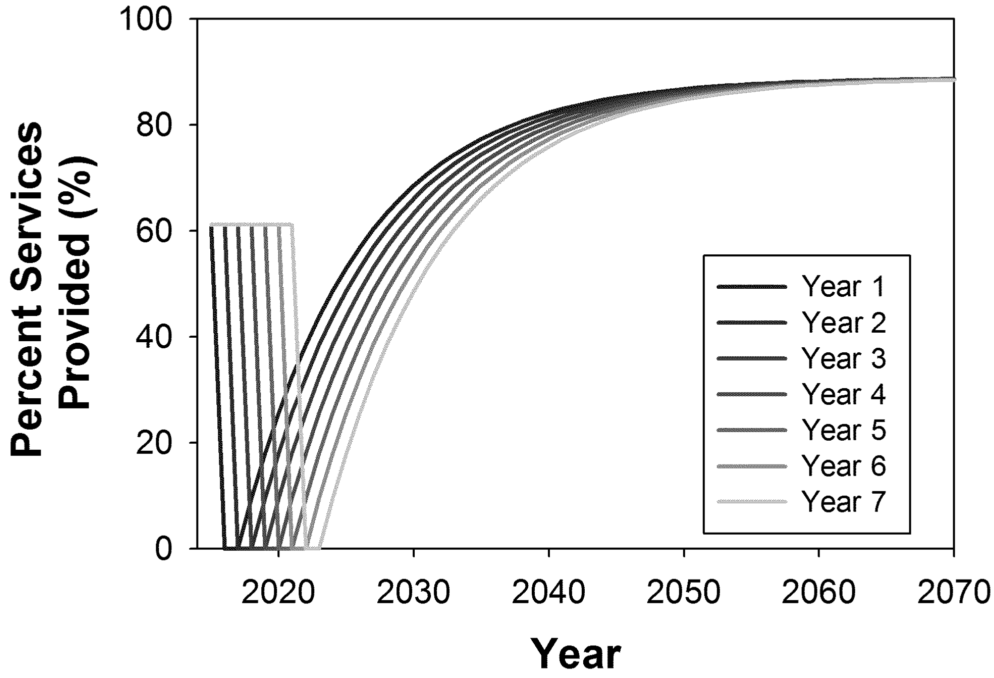
Figure 2



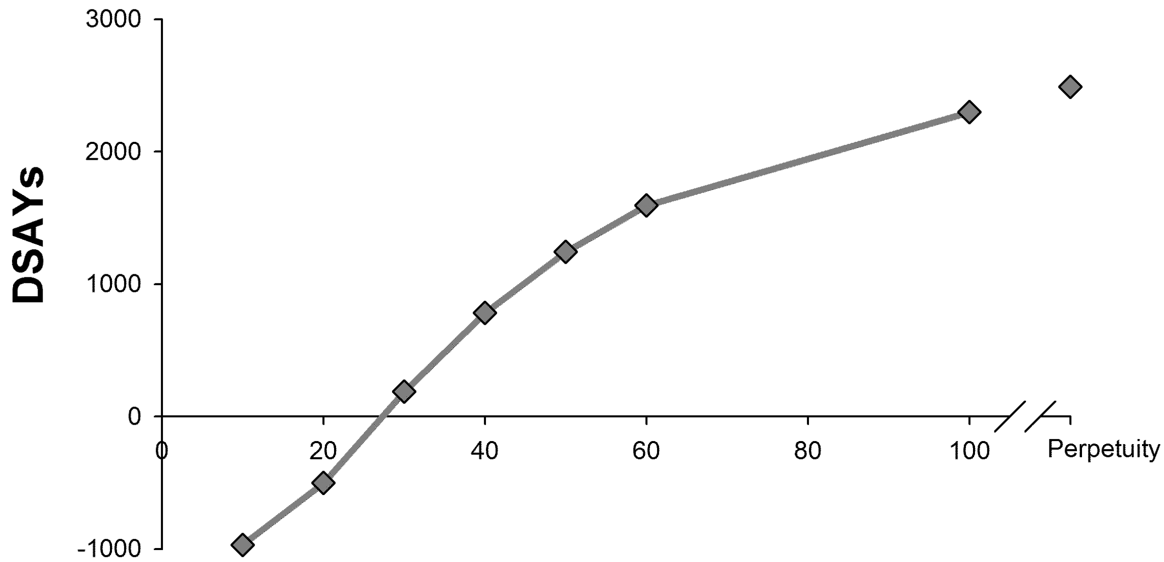
RAMBOLL ENVIRON	Current Land Cover Classifications at the Seven Hills Mine Site	Figure 3



RAMBOLL ENVIRON	Post-Reclamation Land Cover Classifications at the Seven Hills Mine Site	Figure 4



RAMBOLL ENVIRON	Incremental Impacts to and Recovery of Onsite Palustrine Forested (PFO) Wetlands	Figure 5



DSAY: discounted service acre year
NESA: net ecosystem service analysis

RAMBOLL ENVIRON	Preliminary NESA Results: Onsite Wetlands	Figure 6